# Optimal Environmental Policy Differentials under Emissions Constraints

Florax, R.J.G.M.; Mulatu, A.; Withagen, C.A.A.M.

2003

TI 2003-080/3
Tinbergen Institute Discussion Paper

# Optimal Environmental Policy Differentials under Emissions Constraints

*Raymond J.G.M. Florax*[1,2]
*Abay Mulatu*[3]
*Cees A. Withagen*[1,4,5]

*[1] Department of Spatial Economics, Faculty of Economics and Business Administration, Vrije Universiteit Amsterdam, the Netherlands, [2] Regional Economics Applications Laboratory (REAL), University of Illinois, Urbana-Champaign, USA, [3] Department of Economic History, London School of Economics, London, UK, [4] Tinbergen Institute, [5] Department of Economics, Tilburg University, the Netherlands.*

**Tinbergen Institute**
The Tinbergen Institute is the institute for economic research of the Erasmus Universiteit Rotterdam, Universiteit van Amsterdam, and Vrije Universiteit Amsterdam.

**Tinbergen Institute Amsterdam**
Roetersstraat 31
1018 WB Amsterdam
The Netherlands
Tel.: +31(0)20 551 3500
Fax: +31(0)20 551 3555

**Tinbergen Institute Rotterdam**
Burg. Oudlaan 50
3062 PA Rotterdam
The Netherlands
Tel.: +31(0)10 408 8900
Fax: +31(0)10 408 9031

# Optimal environmental policy differentials under emissions constraints

**Raymond J.G.M. Florax**
Department of Spatial Economics, Free University, Amsterdam, The Netherlands, and
Regional Economics Applications Laboratory (REAL), University of Illinois,
Urbana-Champaign, USA

**Abay Mulatu**
Department of Economic History, London School of Economics, London, UK

**Cees A. Withagen**[1]
Department of Spatial Economics, Free University, Amsterdam, and
Department of Economics, Tilburg University, Tilburg, The Netherlands

**Key words:** ecological dumping, general equilibrium, emissions constraints, Kyoto protocol
**JEL code:** D6, F12, Q28

**Abstract**
Is there a case to be made for preferential treatment of the exposed sector in an economy when compliance to an aggregate emissions constraint induced by an international environmental agreement is mandatory? This question is being debated in many countries, including The Netherlands, in the context of the implementation of the Kyoto protocol. We address this issue in a general equilibrium framework in this paper, and theoretically cover several market structures, including perfect competition, oligopoly and the large country case. Our main finding is that in many circumstances preferential treatment is not warranted from the point of view of maximizing social welfare.

[1] Corresponding author. Department of Spatial Economics, Faculty of Economics, Free University Amsterdam, De Boelelaan 1105, 1081 HV Amsterdam, The Netherlands. E-mail: cwithagen@feweb.vu.nl

## 1. Introduction

The tension between trade and the environment is oftentimes caused by the supposition that governments exploit the responsiveness of trade to environmental policy in order to obtain favorable trade outcomes. The allegation is that “over-lax” environmental standards or taxes can serve governments as a non-tariff barrier instrument. As a result, there is a strong case to be made for the analysis of domestic environmental policies within the domain of international trade (Esty 2001).

Environmentalists voice their concerns along a different line. Their worry is not that environmental policy is used as a barrier to free trade. On the contrary, environmentalists maintain that trade liberalization not only damages the environment through increased production, consumption and transportation of goods, but trade liberalization also induces policy makers deprived of trade policy instruments to set “over-lax” environmental standards or taxes because of competitiveness concerns (Ulph 1999). The question whether benevolent governments actually have an incentive to implement an “over-lax” environmental policy for reasons of international competitiveness of the domestic industry, is a fundamental question that is treated in the so-called “ecological dumping” literature. Seminal work in this literature includes Barrett (1994) and Rauscher (1994). We briefly discuss these as well as a series of more recent papers (Elbers and Withagen 2002a,b, 2003; Neary 2003), and refer interested readers to Ulph (1997) and Rauscher (1998) for surveys of the literature.

Barrett (1994) investigates the issue of ecological dumping in a *partial* equilibrium setting. The model considers two countries and two cases. The first case concerns a situation with many domestic firms that have a substantive impact on the world market. The other case involves a domestic firm producing for a third market only that competes in a Cournot or Bertrand fashion with a similar foreign firm. Each government determines unilateral or bilateral strategic environmental policy prior to firms choosing their output/price levels. The governments’ objectives are to maximize the difference between the firms’ profits and (monetized) local pollution damage arising from production. Barrett shows that strategic considerations of the government to set “over-lax” or “over-stringent” environmental policy goals, in the sense of below or above the level of marginal damage of pollution, depend on the market structure. If the domestic industry is a monopoly on the world market, it is optimal that the government in a second-best[2] world adopts an “over-lax” environmental standard. In the case of a Bertrand oligopoly, where competition materializes in prices rather than quantities, the government has an incentive to adopt “over-stringent” standards, contrary to the case of Cournot competition.

Unlike Barrett (1994), Rauscher (1994) considers the issue of ecological dumping in a *general* equilibrium setting and focuses on whether or not a welfare-maximizing social planner would apply “over-lax” environmental standards in the tradable sector as compared to the non-tradable (domestic) sector. He finds that in a fully competitive world market the government in a small open economy has no incentive to deviate from the first-best rule of setting environmental standards corresponding to marginal social damage. This result applies for a large country as well, as long as there are no second-best constraints on policy. Rauscher also conjectures that with a monopolistic or oligopolistic structure of world markets in a second-best world, it would not necessarily pay governments to engage in eco-dumping.

Neary (2003) investigates the issue in a somewhat different framework using the dual techniques of GNP and expenditure functions for production and consumption, respectively. The framework accommodates standards or taxes, competition via quantities or prices, and initial states of first- and second-best solutions. Similar to Rauscher (1994), he shows that for a small competitive open economy social welfare maximization dictates first-best environmental policy rules and free trade. The incidence of persistent distortions in the economy, such as tariffs, calls for a systematic deviation from efficient environmental policy rules. In the case of a large country, tariffs and efficient environmental policy rules constitute the socially desirable policy-

[2] Second-best refers here and in the remainder of the paper to the government’s inability to use direct trade policies.

mix. For the oligopolistic market structure, Neary resorts to a partial equilibrium setting and he analyzes one of the several scenarios also considered by Barrett (1994).[3] Neary (2003) establishes the same conclusion: deviations from first-best rules, the direction depending on the form of competition, are justified only if we assume that the government is unable to use appropriate trade policies.

Elbers and Withagen (2002a) use a *general* equilibrium model again, and present detailed results for monopolistic and oligopolistic structures of the world market. For both the small and large country cases with perfect competitive domestic markets, they obtain results similar to Rauscher (1994). They also consider the case of an oligopoly with a single domestic firm, in both a partial and a general equilibrium setting, using the Cournot-Nash equilibrium concept, with governments acting on the Cournot assumption of taking the foreign firm's actions as given. In this case, they find that the government will set uniform emission taxes equal to marginal social damage for both the export and the sheltered sector. However, in a partial equilibrium model, emission taxes would be set lower than marginal damage for the export sector if the government induces the home oligopoly to supply as a Stackelberg quantity leader, as was shown in a different context by Barrett (1994). It is also shown that, in a general equilibrium setting, the result may be reversed and hence more stringent taxation can be optimal. This result contrasts sharply with some of the results derived in a partial equilibrium setting. For Bertrand competition, a similar reversal holds (see Elbers and Withagen 2002b, 2003).

In the present paper, we examine the issue of ecological dumping in a different policy context. Specifically, we assume a given level of emission for an economy that cannot be surpassed. As a result, emission is not modeled as an argument in the welfare function but rather as a constraint to be observed. The government behavior is then restricted to setting

[3] Specifically, he analyzes the case of two firms, one home firm and the other foreign, competing in a Cournot or a Bertrand fashion in a third market. Only the home government intervenes by setting environmental policy before the firms choose their actions.

environmental policies in such a way that emissions are kept within the upper limit. The case we investigate in detail is whether the government has incentives, from a social welfare perspective, to give preferential treatment to the exposed exporting sector over the sheltered sector. This different policy context mimics the actual practice of countries trying to meet agreements like the Kyoto Protocol that determines concrete targets of carbon dioxide emission reduction (Article 3, United Nations Conventions on Climate Change):

> The Parties included in Annex I shall, individually or jointly, ensure that their aggregate anthropogenic carbon dioxide equivalent emissions of the greenhouse gases listed in Annex A do not exceed their assigned amounts, calculated pursuant to their quantified emission limitation and reduction commitments inscribed in Annex B and in accordance with the provisions of this Article, with a view to reducing their overall emissions of such gases by at least 5 per cent below 1990 levels in the commitment period 2008 to 2012.

In such a policy setting, ecological dumping or preferential treatment of the exposed sector is a pivotal issue. For example, in The Netherlands, a government advisory committee recently recommended the introduction of a hybrid system of tradable permits that is more favorable to exposed industries than to sheltered industries.

The remainder of this paper is organized as follows. In Section 2, we introduce our basic model with features largely identical to the models discussed above. Section 3 presents the first order conditions for the first-best optimum and its implementation. In Section 4, we consider the large country case in the second-best optimum where trade policies cannot be used. Section 5 investigates the issue in an oligopolistic structure of the world market. Section 6 concludes and provides policy conclusions.

## 2. A general equilibrium model of trade and international pollution bans

In this section, we present a model of international trade with pollution bans. The model closely resembles the models used in earlier work by Elbers and Withagen (2002a,b and 2003). The policy context is different, however, because we impose an upper bound on the emissions.

Assume an economy with five types of commodities: three consumer commodities, capital and a raw material. The first consumer commodity is produced and consumed domestically only. Production takes place in the so-called sheltered sector. We assume that this sector contains many price-taking firms, allowing us to work with an aggregate technology described by a production function $F_1$ that has capital $k_1$ and the raw material $y_1$ as inputs. The function $F_1$ has the following properties: $F_{1k} > 0, F_{1y} > 0$, $F_{1kk} < 0$, and $F_{1yy} < 0$, where letters in subscripts denote partial derivatives. Domestic consumption of the good produced in the sheltered sector is denoted by $c_1$.

The second class of consumer commodities is produced in the exposed sector. The commodities can be heterogeneous, so the exposed sector produces $n\ (n \geq 1)$ varieties, indexed by $i = 1, 2, ..., n$. The aggregate production of variety $i$ is described by a production function $F_2^i$, employing capital $k_2^i$ and a raw material $y_2^i$ as inputs. The function $F_2^i$ has the following properties: $F_{2k}^i > 0, F_{2y}^i > 0,\ \ F_{2kk}^i < 0$, and $F_{2yy}^i < 0$. The output is partially consumed domestically $(c_2^i)$, with $c_2$ representing the aggregate consumption vector $c_2 = (c_2^1, c_2^2, ..., c_2^n)$, and the remainder is exported $(x_2^i)$. A precise description of the market conditions follows below.

The third consumer commodity cannot be produced domestically. It needs to be imported. Consumption is denoted by $c_3$. This commodity is taken as the numéraire.

Capital cannot cross the borders and is considered internationally immobile.[4] Capital can, however, be shifted from one domestic sector to another. Gordon and Bovenberg (1996) provide

[4] The immobile factor is referred to as capital, but if applicable one can also think of labor as the immobile factor.

empirical as well as theoretical support for the assumption of international immobility of capital.[5] The economy's endowment of capital is given by $\bar{k}$. The rate of return on capital is denoted $r$.

The raw material can be conceived of as a fossil fuel. We do not consider an inter-temporal setting and therefore neglect the exhaustibility of the resource from which the raw material is extracted. The raw material is in principle freely available in unlimited amounts, although processing of the raw material causes pollution. Using one unit of the raw material entails one unit of emission: so no abatement technology is available. Due to international environmental agreements, there is an upper bound $\bar{y}$ on the use of pollutants or energy. In order to comply with the international norm, the government levies emission taxes $\tau_1$ and $\tau_2^i$ $(i = 1, 2, ..., n)$ per unit of raw material used in the sheltered sector and in the firms of the exposed sector, respectively. In principle, the emission taxes can be differentiated within as well as between sectors. Tax revenues are recycled to consumers in a lump sum fashion.

Income of the representative *consumer* consists of three parts. The first component is the value of the capital endowment $r\bar{k}$, which is the only consumer's endowment. The second component of income consists of the recycled emission tax revenues $\tau_1 y_1 + \sum_{i=1}^n \tau_2^i y_2^i$. The final component is the profits of the firms. Profits in the sheltered sector amount to $\pi_1 = p_1 F_1(k_1, y_1) - rk_1 - \tau_1 y_1$, where $p_1$ is the output price. Profits accruing to the consumer from the exposed sector are $\pi_2 = \sum_{i=1}^n \left\{p_2^i F_2^i(k_2^i, y_2^i) - rk_2^i - \tau_2^i y_2^i\right\}$, where $p_2^i$ is the world market price. The exposed sector can be given an export subsidy, in which case profits increase, but in effect, the consumers pay for the subsidy since the government's budget is balanced. The "net" profits from the exposed sector accruing to the consumer are then $\pi_2$. Alternatively, the

[5] In an attempt to explain the empirical evidence on international immobility of capital, Gordon and Bovenberg (1996) single out asymmetric information between domestic investors and foreign investors as the most important factor. They argue that foreign investors are at a disadvantage due to several reasons emanating from lack of information regarding issues such as purchase prices of assets and inputs, output markets, and future government policies.

government can impose an import tariff on the third consumer commodity, but such a tariff does not alter the consumer's budget either. Under the assumption of full employment of capital (in a situation where firms maximize profits), total income boils down to $p_1 F_1 + \sum_{i=1}^{n} p_2^i F_2^i$.

Preferences involve consumption only, and consumer utility is represented by $U(c_1, c_2, c_3)$. The utility function is assumed to have all the commonly desired properties, such as concavity, differentiability and monotonicity. Equilibrium on the current account of the balance of payments completes the model.

**3. First-best optimum and implementation**

The first-best optimum is the allocation that maximizes social welfare subject to the restrictions imposed by technology and energy use, initial endowments of capital, and the condition of equilibrium on the current account of the balance of payments. In the present section, it is assumed that all commodities, the Type 1 and each of the Type 2 commodities, are supplied by a large number of price taking domestic firms. The Type 2 commodities are also traded on world markets with either perfect competition or where the country under consideration is "large." In the latter case, the individual producers are still price taking, but the country as a whole is a large supplier. Denoting the aggregate world supply of commodity $i$ of Type 2 by domestic producers by $x_2^i$, we write $p_2^i = p_2^i(x_2^i)$ for the inverse world demand function. We will not focus on imperfect competition on domestic markets, in order to be able to concentrate on the issue of international trade and (strategic) environmental policy.

In mathematical terms, the first-best optimum is the solution of the maximization of $U(c_1, c_2, c_3)$ subject to:

(3.1) $\quad c_1 = F_1(k_1, y_1)$,

(3.2) $\quad c_2^i + x_2^i = F_2^i(k_2^i, y_2^i), \;\; (i = 1, 2, ..., n)$, (3.3) $c_3 = \sum_{i=1}^{n} p_2^i(x_2^i)x_2^i$ ,

(3.4) $k_1 + \sum_{i=1}^{n} k_2^i = \bar{k}$ ,

(3.5) $y_1 + \sum_{i=1}^{n} y_2^i = \bar{y}$ .

The Lagrangian then reads as:

$$L = U(c_1, c_2, c_3) + \lambda_1[F_1(k_1, y_1) - c_1] + \sum_{i=1}^{n} \lambda_2^i [F_2^i(k_2^i, y_2^i) - x_2^i - c_2^i] +$$
$$\lambda_3[\sum_{i=1}^{n} p_2^i(x_2^i)x_2^i - c_3] + \mu_1[\bar{k} - k_1 - \sum_{i=1}^{n} k_2^i] + \mu_2[\bar{y} - y_1 - \sum_{i=1}^{n} y_2^i],$$

and the necessary conditions for an interior solution are:

(3.6) $U_{c_1} = \lambda_1$; $U_{c_2^i} = \lambda_2^i, i = 1, 2, ..., n$; $U_{c_3} = \lambda_3$,

(3.7) $\lambda_1 F_{1k} = \mu_1$; $\lambda_1 F_{1y} = \mu_2$,

(3.8) $\lambda_2^i F_{2k}^i = \mu_1$; $\lambda_2^i F_{2y}^i = \mu_2, i = 1, 2, ..., n$,

(3.9) $\lambda_2^i = \lambda_3 p_2^i [1/\varepsilon_i + 1], i = 1, 2, ..., n$.

The multipliers $\lambda_1, \lambda_2^i$ $(i = 1, 2, ..., n), \lambda_3, \mu_1$ and $\mu_2$ correspond with the first consumer commodity, the exported commodities, the imported commodity, capital, and energy, respectively. The price elasticities of world demand are $\varepsilon_i$ $(i = 1, 2, ..., n)$, which in an optimum are smaller than $-1$.

The equations in (3.6) articulate that marginal changes in the consumer's utility arising from marginal changes in the consumption of the commodities equal the shadow prices.

Equations (3.7) and (3.8) state that the marginal value of relaxing the constraint on the capital endowment, $\mu_1$, is equal to the marginal product of capital. Similarly, the marginal value of relaxing the constraint on raw material (or emissions), $\mu_2$, is equal to the product of the marginal product of raw material (or emissions). Finally, condition (3.9) represents the maximization of the net revenues from exporting Type 2 commodities. In the sequel, asterisks denote the first-best values.

The first-best optimum is realized in a decentralized setting by the following familiar rules. First, levy an export tax on the exported commodities such that the domestic price of commodity $i$ of Type 2, $\tilde{p}_2^i$, equals $p_2^{*i}\left(1+1/\varepsilon_i^*\right)$, in order to exploit the monopoly power on the world market. Second, impose an emissions tax $\tau = \mu_2^* / \lambda_3^*$.[6] Consequently, there need not be preferential treatment of the exporting sectors: there is a uniform emissions tax. This is a nice result in the light of the debate on preferential treatment of the export sector. It means that export sectors are not charged with a lower emission tax as compared to other sectors. Moreover, export products should be subject to an export tax. For the case of perfect competition, where the price elasticity is $-\infty$, trade policy is not necessary at all. Alternatively, the government can propose a tradable permits system in which both sectors are treated equally. Hence, contrary to the $CO_2$ permit system proposal recently suggested in The Netherlands, the exposed sector should not get preferential treatment.

We can summarize these results in the following proposition:

**Proposition 1**

a) *If all world markets are competitive, the first-best optimum is realized by imposing a uniform emission tax or by implementing a uniform system of tradable permits across sectors.*

[6] One can straightforwardly derive this result by considering the optimization problems of all individual agents in the economy. Since the utility and the production functions are concave and the damage function is convex, the first order necessary conditions are sufficient.

b) *For markets where the country has monopoly power an export tariff should be imposed, maintaining a uniform system of emission taxes or tradable permits.*

**4. Second-best optimum in the case of a large country**

The situation becomes more complicated when, due to international regulations, trade policy instruments in the form of export tariffs cannot be used. We make a distinction between two cases. In the first case, we study an exposed sector consisting of many price-taking firms. We perform a local analysis of the case where the government has imposed a uniform emissions tax, and address the issue whether deviations from this policy can increase social welfare. We also discuss an example allowing for the implementation of globally optimal taxation. The second case is concerned with the situation where the exporting sector behaves as a large player on the world market.

In a competitive economy, the representative consumer maximizes utility subject to the budget constraint. Hence:

$$(4.1) \qquad U_{c_1} / p_1 = U_{c_2^i} / p_2^i = U_{c_3} \ (i = 1, 2, ..., n).$$

It follows from profit maximization that:

$$(4.2) \qquad p_1 F_{1k} = p_2^i F_{2k}^i = r, \ \ p_1 F_{1y} = \tau_1 = p_2^i F_{2y}^i = \tau_2^i \ \ (i = 1, 2, ..., n).$$

Feasibility and equilibrium on the current account require:

$$(4.3) \qquad c_1 = F_1, \ \ c_2^i = F_2^i - x_2^i \ \ (i = 1, 2, ..., n), \ \ c_3 = \sum_{i=1}^{n} x_2^i (p_2^i) p_2^i .$$

Suppose the government has set optimal uniform emissions taxes where optimal implies there is no other uniform emissions tax that yields higher social welfare. We are interested in the question how welfare changes if the government deviates from this policy, given the market behavior by individual agents. With equal emissions taxes the marginal change in welfare $(dU)$ can be written as (see the Appendix for the derivation):

(4.4) $$dU = U_{c_3} \sum_{i=1}^{n} x_2^i dp_2^i.$$

Consequently, the effect of a change in environmental instruments depends on the change in the terms of trade. If a raise in the emissions tax increases the terms of trade, it is optimal to deviate from uniform taxation. We cannot infer any additional general statement from the results derived above, but the likelihood of optimality of a system of undifferentiated taxes is small. By contradiction, this can be seen as follows. Consider the case of a single exportable ($n = 1$), and constant returns to scale in production. Suppose that the Engel curves are monotonic, and that an increase in $\tau_2$ results in a lower $p_2$, and hence in lower utility. Since the price elasticity of demand is larger than unity in absolute value, export revenues increase, thereby increasing consumption of the imported commodity. This can only happen if real income has increased, but then domestic consumption of the exportable has increased as well. This also holds for the consumer commodity produced in the sheltered sector, because its price is lower too. In order to have zero profits in the exposed sector the rental rate must decrease, implying a lower price in the sheltered sector. Hence, each consumption rate increases, which contradicts decreased welfare. The extension to multiple exportables is straightforward. These observations lead to our second proposition:

**Proposition 2**

*For technologies exhibiting constant returns to scale and normal domestic demand, it is optimal to (marginally) deviate from uniform emissions taxation by imposing a stricter emissions tax on at least one exposed sector.*

We now provide an example illustrating Proposition 2. In addition, we derive the overall optimal emissions taxes, going beyond merely considering marginal deviations. Suppose, there is just one exported commodity $(n=1)$, utility is logarithmically additive, production functions are Cobb-Douglas, and world demand for the exported commodity is iso-elastic:

(4.5) $$U(c_1, c_2, c_3) = \ln c_1 + \ln c_2 + \ln c_3,$$

(4.6) $$F_1(k_1, y_1) = k_1^{\alpha} y_1^{1-\alpha},$$

(4.7) $$F_2(k_2, y_2) = k_2^{\beta} y_2^{1-\beta},$$

(4.8) $$p_2(x_2) = x_2^{1/\varepsilon}.$$

Utility maximization subject to the budget constraint implies $p_1 c_1 = p_2 c_2 = c_3 = \frac{1}{3}[p_1 F_1 + p_2 F_2]$. Together with the conditions for market equilibrium, $F_1 = c_1$ and $F_2 = c_2 + x(p_2)$, this yields $p_1 c_1 = p_2 x(p_2)$, $c_2 = x(p_2)$, $c_3 = p_2 x(p_2)$. Hence, $c_2 = \frac{1}{2} F_2$. Factor demands are:

(4.9) $$k_1 = \frac{\alpha}{r} p_1 F_1 = \frac{\alpha}{r} p_2 x_2(p_2),\quad y_1 = \frac{1-\alpha}{\tau_1} p_1 F_1 = \frac{1-\alpha}{\tau_1} p_2 x_2(p_2),$$

(4.10) $$k_2 = \frac{\beta}{r} p_2 F_2 = \frac{\beta}{r} 2 p_2 x_2(p_2),\quad y_2 = \frac{1-\beta}{r} p_1 F_1 = \frac{1-\beta}{\tau_2} 2 p_2 x_2(p_2).$$

It follows that:

$$(4.11)\quad \frac{k_1}{k_2} = \frac{\alpha}{2\beta}\,,\ \frac{y_1}{y_2} = \frac{(1-\alpha)\tau_2}{2(1-\beta)\tau_1}\,,$$

and by using $k_1 + k_2 = \bar{k}$, we obtain:

$$(4.12)\quad k_1 = \frac{2\beta}{\alpha + 2\beta}\bar{k},\ k_2 = \frac{\alpha}{\alpha + 2\beta}\bar{k}.$$

Therefore, in a general equilibrium, the respective capital inputs are proportional to the total available stock, the proportions being determined by the parameters of the production functions.

Subsequently, we consider the problem of maximizing total welfare, with respect to the polluting inputs:

$$\text{max} \qquad \ln k_1^{\alpha} y_1^{1-\alpha} + \ln \tfrac{1}{2} k_2^{\beta} y_2^{1-\beta} + \ln(\tfrac{1}{2} k_2^{\beta} y_2^{1-\beta})^{1+1/\varepsilon}$$

$$\text{subject to} \qquad y_1 + y_2 = \bar{y}\,.$$

This maximization problem yields:

$$(4.13)\quad y_1 = \frac{(1-\alpha)}{(1-\alpha) + (1-\beta)(2+1/\varepsilon)}\bar{y}\,,\ y_2 = \frac{(1-\beta)(2+1/\varepsilon)}{(1-\alpha) + (1-\beta)(2+1/\varepsilon)}\bar{y}.$$

It follows from (4.9) and (4.10) that:

$$(4.14) \qquad \tau_2 = \frac{2}{2+1/\varepsilon}\tau_1.$$

Since the price elasticity of world demand is negative, this result shows that the export sector should be taxed more heavily than the sheltered sector in all circumstances and irrespective of the capital stock, because environmental policy does not change with changes in national income, embodied in a larger capital stock. In addition, in a tradable permits system, the system should be dual, allowing for a separate permits market in each sector. We summarize this result in the following proposition:

**Proposition 3**

*Under the assumptions that a country is a large player on the world market, there is one exported commodity, utility is logarithmically additive, production functions are Cobb-Douglas, and world demand for the exported commodity is iso-elastic, it is optimal in a second-best world to impose a higher emission tax on the exporting sector as compared to the sheltered sector. Alternatively, a system of tradable permits should be dual, allowing for separate sectoral permits markets.*

An additional consideration may be useful in determining the optimal policy design. If an unconstrained tradable permit system is implemented, each individual firm in the export sector will demand more emission permits and supply more in the world market. As a result, the total supply of the export sector is higher than optimal. In the case of more than one export sector, this implies that separate sectoral permits markets should be established. This policy is generally more difficult to implement, and it will as well be intricate to ensure perfect competition. A policy design based on differentiated emissions taxes is therefore likely to be more appropriate.

We now consider the case where the export sectors by themselves act as large players on the world market. In order to avoid complications related to modeling domestic market power, we assume that the exportables are not consumed domestically. Profit maximization by the producer of exportable $i$ then entails:

(4.15) $[(dp_2^i / dx_2^i)x_2^i + p_2^i]F_{2k}^i = r,$

(4.16) $[(dp_2^i / dx_2^i)x_2^i + p_2^i]F_{2y}^i = \tau_2^i.$

It is straightforward to see that $dU = 0$ if $\tau_1 = \tau_2^1 = \tau_2^2 = ... = \tau_2^n$ (see the Appendix for details). Hence, when the export sector by itself is capable of capturing the monopoly rents, there is no need to differentiate emission taxes.

Summing up, in both the small and large country cases there is no need for preferential treatment of the exposed sector relative to the domestic sector in the first-best world. However, the issue of strategic environmental policy is in the limelight because of the existent political tension between domestic environmental policy-making and trade liberalization. A first-best world analysis is therefore at best an interesting theoretical exercise. Concurrently, a second-best approach is necessary. In a second-best world, where governments are deprived of trade policy instruments, a large-country government will be induced to resort to "over-stringent" environmental policy if the firms constituting the export sector are small. No preferential treatment is warranted, however, if the exporting firms are by themselves capable of capturing the monopoly rents.

**5. Oligopoly**

The preceding sections considered the issue of strategic environmental policy for price-taking and monopoly power market structures. In many instances, markets are however better described by an oligopolistic structure, giving rise to strategic interaction among firms as well as among governments.

The literature of optimal environmental policy in an oligopolistic world market is based on the strategic trade literature pioneered by Spencer and Brander (1983), and Brander and Spencer (1985). The core issue in this literature is whether welfare can be enhanced by raising the supply of the export industry in the home country for a given supply by the foreign firms. Such a governmental objective may be fulfilled through pre-commitment of subsidy provisions. A production (export) subsidy and an economy-wide research and development subsidy are typical examples of such a policy. Pre-commitments by the government enable the domestic exporting firm to play the strategic game as a Stackelberg leader rather than in a Nash fashion.

Along the same line, the strategic environmental policy literature addresses the issue whether an "over-lax" environmental policy could be used as an alternative to providing subsidies to domestic exporting firms. Unlike other domestic subsidies, however, over-lax environmental regulations also entail a social cost in terms of increased pollution (Rauscher 1994, p. 832).

The work on optimal environmental policy in an oligopolistic world market has mainly been concerned with a partial equilibrium framework. Barrett (1994) and Neary (2003) consider two firms, one home and the other foreign, competing on a third market. They show that in the case of Cournot competition, welfare maximization indeed dictates an "over-lax" environmental policy in the sense that the home firm pays less than the Pigouvian tax corresponding to the marginal damage of charging yielding. This result is reversed in the case of Bertrand competition.

Rauscher (1994), and Elbers and Withagen (2002a,b) consider the issue in a general equilibrium setting. Their analyses go beyond the question whether or not environmental policy yields Pigouvian outcomes, by considering discrimination in the stringency of environmental policy between the domestic and the export sectors. Elbers and Withagen (2002a,b) show that the partial equilibrium recommendation may not hold in the case of a general equilibrium approach.

In the policy context of this paper, emissions are not incorporated in the welfare function but there is an upper bound on emissions. The government derives the demand for emissions from the firms' cost functions and fixes emission taxes by targeting emission levels corresponding to the upper bound of the emissions use. Attempts to increase production of the export sector by lowering the tax in this sector should necessarily be accompanied by a rise in the tax imposed on the domestic sector. This implies that, unlike in the models discussed above, a mere trade off between additional emissions and additional welfare is absent because of the binding resource constraint. Consequently, the export sector cannot be considered in isolation and a general equilibrium approach is in order.

We use the superscripts $f$ and $h$ to refer to the foreign and home country, respectively, and consider the case of a single domestic producer ($n=1$) acting as an oligopoly on the world market. There is no domestic consumption of the export commodity. The inverse demand function is then written as $p_2(x_2) = p_2(x_2^h + x_2^f)$, and profit maximization in the exposed sector, taking foreign supply as given, yields (4.15) and (4.16) with the index $i$ deleted. Starting from a general equilibrium the following welfare change can be derived in a way quite similar to the derivation of (4.4):

$$(5.1) \qquad dU^h = U_{c_3}\left\{\left[\tau_1^h dy_1^h + \tau_2^h dy_2^h\right] + \frac{dp_2}{dx_2} x_2^h dx_2^f\right\}.$$

Hence, if foreign supply is taken as given by the home government $(dx_2^f = 0)$, it is optimal to set equal emissions taxes or treat the two sectors of the economy equally. However, things change if by manipulating the emissions tax rates foreign supply can be manipulated as well. In that case, starting from equal taxes, a policy that reduces foreign supply is beneficial, as can be seen from the third term on the right-hand side of (5.1).

The interesting case is therefore the case where the foreign country is a Stackelberg follower, and the home country is the Stackelberg leader. The game can be formulated as follows. There are four players at several levels. It is innocuous to assume that the firms are Nash players on the world market, so they take each other's supply as given. One way to model the game at the government level is to assume that the foreign government takes the tax rates set by the home government as given, and maximizes its own welfare given these taxes. However, matters are slightly more complicated because they are intertwined.

The tax structure in the home country does not fully determine the home country's supply to the world market, because the home country's supply is also determined by the supply of the foreign firm, which is subject to taxes in the foreign country. In order to circumvent this complication we will assume that the foreign government takes world market supply by the home country as given, and subsequently determines its own optimal tax structure. As a result, for any given $x_2^h$ the foreign government sets (uniform) emissions taxes that maximize social welfare. These taxes also generate foreign supply that can hence be written as $x_2^f(x_2^h)$. Subsequently, the home government takes the overall reaction function of the foreign country into account in determining its own optimal taxes. For the outcome of the game, the slope of the foreign reaction function $x_2^f(x_2^h)$ is obviously crucial. Unfortunately, an analytical solution for this specific game cannot be straightforwardly obtained. We therefore use the functional forms of (4.5)–(4.8), taking into account that domestic consumption of the second commodity equals zero, and resort to numerical simulations. We assume identical production structures and preferences in the two countries. For both countries, the inputs in the sheltered sector are cost minimizing in the sheltered sector, and the equilibrium price lies on the factor price frontier:

$$(5.2) \qquad \frac{y_1}{k_1} = \frac{r}{\alpha}\frac{1-\alpha}{\tau_1}, \quad p_1 = \left(\frac{r}{\alpha}\right)^{\alpha}\left(\frac{\tau_1}{1-\alpha}\right)^{1-\alpha}.$$

It follows from profit maximization in the exposed sector in the home country, that:

(5.3) $\quad \dfrac{y_2}{k_2} = \dfrac{r}{\beta}\dfrac{1-\beta}{\tau_2}, \; \left(x_2^h + x_2^f\right)^{1/\varepsilon}\left[1 + \dfrac{x_2^h}{\varepsilon[x_2^h + x_2^f]}\right] = \left(\dfrac{r}{\beta}\right)^{\beta}\left(\dfrac{\tau_2}{1-\beta}\right)^{1-\beta}.$

The definitions of (3.4) and (3.5) hold as well and, in the case at hand, utility maximization on the part of the consumers implies $p_1 F_1 = p_2 F_2$.

We consider the following set of initial parameters in the simulations, and report on sensitivity experiments in Table 1.[7] Initial capital endowments are 10 and 5 in the home and foreign country, respectively. The resource or emissions upper limit is 6 in both the home and the foreign country. The price elasticity of world demand is –2. The production elasticity of capital is 0.75 in both sectors for both countries. Given these initial parameter values, the reaction function of the foreign country is upward sloping. This confirms earlier findings by Bandyopadhyay (1997), and Collie and De Meza (2002) for iso-elastic demand functions. Obviously, if $x^h + x^f / \varepsilon > 0$ and marginal costs are constant in the foreign country, the reaction curve of the foreign country is upward sloping. It is, however, difficult to assess why this result also applies in the current game. Marginal costs are in effect not constant in this case because they depend on foreign supply through the emissions tax rate. Apparently, however, this effect does not reverse the sign of the slope. Moreover, in this base scenario, the optimal emissions tax rate for the exposed sector in the home country is higher than for the sheltered sector (0.106 versus 0.103). Hence, bearing in mind (5.1), and starting from uniform emissions taxes, a relatively higher tax on the exposed sector in the home country induces the foreign country to take steps to reduce its world market supply.

< Table 1 about here >

[7] The simulations have been performed usingMATHEMATICA 5.

In order to examine the sensitivity of the results to the given parameter values, we performed a large number of numerical experiments, and some of the more interesting results are presented in Table 1. The main conclusion emanating from this table is that the optimality of taxing the export sector more heavily than the sheltered sector remains intact for all parameter values used in the simulation experiments.

We also observe, perhaps trivially, that as the production elasticities of capital in the sheltered or the exposed sector increase, both tax rates decline. The reason for this is that the production elasticities of the natural resource decline in the corresponding sector, which in turn implies lower emissions allowing for relaxation of the emissions constraint. Also, as the home capital endowment decreases, both tax rates decrease in order to keep emissions within the constraint. Another observation is that, as the elasticity of world demand for the export commodity increases in absolute value (i.e., becomes more elastic), the ratio of the tax rate on the export sector to the tax rate on the sheltered sector $(\tau_2/\tau_1)$ drops significantly. In effect, for $\varepsilon = -6$, the two tax rates become almost equal. An intuitive explanation of this phenomenon is that a more competitive world market structure, as implied by a larger magnitude of the absolute value of $\varepsilon$, reduces the possibility of retaining surplus by means of strategic policies raising the tax rate on the export commodity. Following an increase in the upper bound on emissions, in effect relaxing the emissions constraint, both tax rates decline because there is now more opportunity to accommodate emissions. Perhaps less obvious is the behavior of the ratio of the tax rates for the different sectors, $(\tau_2/\tau_1)$. This ratio declines with increases in the emissions constraint of the home country. Intuitively, this may be explained by the fact that with a reduced constraint on emissions, the constraint-induced strategic desire of rising $\tau_2$ relative to $\tau_1$ diminishes as well.

## 6. Conclusion

This paper addresses ecological dumping, constituting one of the key topics in the trade-environment literature. The phenomenon of ecological dumping entails that governments, deprived of trade policy instruments due to trade liberalization, will use environmental policies to attain favorable trade outcomes. More specifically, the hypothesis is that governments set over-lax environmental regulation in order to increase their exports. There is a growing literature that analyzes ecological dumping in a partial or general equilibrium setting by incorporating emissions in the welfare function.

We use a different setup. Rather than incorporating emissions in the social welfare function, we assume the implementation of a policy that puts a mandatory upper bound on the emissions. This policy constellation is very realistic because many countries are currently trying to meet restrictions induced by agreements such as the Kyoto Protocol that stipulates concrete targets for carbon dioxide emission reduction**.** We are specifically interested in the question whether it is optimal for a social planner to impose a lower environmental tax on the export (or exposed) sector as compared to the sheltered sector.

We answer this question for various market structures in a general equilibrium setting. In the case of perfect competition with a single domestic monopoly in the world market, there is no incentive for governments to impose a less stringent environmental policy on the exposed exporting sector. In the case of many domestic producers, which can be seen as a monopoly power in the world market, it is optimal for the domestic government, in a second-best world, to impose a more stringent environmental policy on the exposed sector. We show that this result also holds for the case of an oligopoly in a third market. A particularly interesting case refers to the situation where the tax setting behaviors of the foreign and home governments are intertwined. We show numerically that the case in which the home government is allowed to take the overall reaction of the foreign country into account in determining its own optimal taxes, always results in an upward sloped reaction function of the foreign country. More analytical work on this specific case is warranted, however, before we can deduce a more general conclusion.

These theoretical results have implications for the policy debates on globalization and the environment, and the issue of harmonization of environmental policies across countries. The results relieve the frequently debated tension between trade and environmental policy objectives by suggesting that fear of ecological dumping can hardly be substantiated by means of standard neoclassical theory. Obviously, in the real world matters are more complicated than we can currently capture in theoretical microeconomic models. Specifically, the assumption of governments behaving as strict social-welfare maximizing agents aiming to design and implement environmental policies in a socially optimal fashion is open to discussion and can be modified. It is nowadays customary to think of governments as policy brokers bringing together different interest groups with conflicting stakes in policy outcomes. Strictly speaking, it is therefore too early to completely rule out the possibility that policies of ecological dumping can be justified on the basis of social optimality grounds. However, it is equally implausible to expect that the game of interest groups competing for policy influence will necessarily end up in a situation where proponents of eco-dumping will unequivocally dominate the game.

## Appendix

*Derivation of welfare change (4.4)*

Totally differentiating the welfare function $U(c_1, c_2, c_3)$ gives:

$$dU = U_{c_1} dc_1 + \sum_{i=1}^{n} U_{c_2^i} dc_2^i + U_{c_3} dc_3 .$$

It follows from (4.1) and (4.3) that:

$$dU = p_1 U_{c3}[F_{1k} dk_1 + F_{1y} dy_1] + U_{c3}[\sum p_2^i F_{2k}^i dk_2^i + p_2^i F_{2y}^i dy^i - p_2^i dx_2^i]$$

$$+ U_{c3}[\sum x_2^i (p_2^i) dp_2^i + p_2^i \frac{dx_2^i}{dp_2^i} dp_2^i].$$

Upon the use of (4.2) it follows that:

$$dU = U_{c_3}[rdk_1 + \sum rdk_2^i] + U_{c_3}[\tau_1 dy_1 + \sum \tau_2^i dy_2^i] + U_{c_3}[\sum x_2^i (p_2^i) dp_2^i + p_2^i \frac{dx_2^i}{dp_2^i} dp_2^i) dp_2^i]$$
$$- \sum U_{c_3} p_2^i dx_2^i.$$

At the optimum, the resource constraints (3.4) and (3.5) hold. We also have equal emissions taxes, as in (4.2). Hence the first two terms on the right-hand side are zero. Therefore:

$$U_{c3} \sum x_2^i (p_2^i) dp_2^i.$$

*Derivation of welfare change for domestic firms acting as large players on the world market*

Using (4.15) and (4.16) it follows that:

$$dU = U_{c_1} dc_1 + U_{c_3} dc_3$$

$$= p_1 U_{c_3} dF_1(k_1, y_1) + U_{c_3} \sum_{i=1}^{n} p_2^i (x_2^i) x_2^i$$

$$= U_{c_3} p_1 [F_{1k} dk_1 + F_{1y} dy_1] + U_{c_3} \sum_{i=1}^{n} [\frac{dp_2^i}{dx_2^i} x_2^i + p_2^i][F_{2k}^i dk_2^i + F_{2y}^i dy_2^i]$$

$$= U_{c_3} \{r[dk_1 + \sum dk_2^i] + \tau_1 dy_1 + \sum \tau_2^i dy_2^i\} = 0$$

## References


Bandyopadhyay, S. (1997) Demand elasticities, asymmetry and strategic trade policy, *Journal of International Economics* **42**, 67–177.

Barrett, S. (1994) Strategic environmental policy and international trade, *Journal of Public Economics* **54***,* 325–38.

Brander, A. and Spencer, B. (1985) Export subsidies and international market share rivalry, *Journal of International Economics* **18**, 83–100.

Brander, J. and Taylor, S. (1997) International trade between consumer and conservationist countries, *Resource and Energy Economics* **19**, 267–97.

Collie, D. and Meza, D. de (2002) Comparative advantage and the pursuit of strategic trade policy, Cardiff University (mimeo).

Esty, D. (2001) Bridging the trade-environment divide, *Journal of Economic Perspectives* **15**, 113–30.

Elbers, C. and Withagen, C. (2002a) Environmental regulation and international trade: A general equilibrium approach, in: J. List and A. de Zeeuw (eds.), *Recent Advances in Environmental Economics*, Cheltenham: Edward Elgar, pp. 98–118.

Elbers, C. and Withagen, C. (2002b) Environmental policy and Bertrand competition: A general equilibrium approach, in: C. Hommes, R. Ramer and C. Withagen (eds.), *Equilibrium, Markets and Dynamics*, Heidelberg: Springer-Verlag, pp. 183–95.

Elbers, C. and Withagen, C. (2003) Environmental policy and international trade: Are policy differentials optimal?, in: L. Marsiliani, M. Rauscher and C. Withagen (eds.), *Environmental Policy in an International Perspective*, Dordrecht: Kluwer, pp. 173–91.

Gordon, R. and Bovenberg, L. (1996) Why is capital so immobile internationally? Possible explanations and implications for capital income taxation, *American Economic Review* **86,** 1057–75.

Helpman, E. and Krugman, P. (1985) *Market Structure and Foreign Trade,* Cambridge, MA: MIT Press.

Neary, P. (2000) International trade and the environment, University College Dublin (mimeo).

Rauscher, M. (1994) On ecological dumping, *Oxford Economic Papers* **46**, 822–40.

Rauscher, M. (1997), *International Trade, Factor Movements, and the Environment,* Oxford: Oxford University Press.

Spencer, B. and Brander, A. (1983) International R&D rivalry and industrial strategy, *Review of Economic Studies* **50**, 707–22.

Ulph, A. (1997) International trade and the environment: A survey of recent economic analysis, in: H. Folmer and T. Tietenberg (eds.), *The International Yearbook of Environmental and Resource Economics 1997/1998,* Aldershot: Edward Elgar, pp. 205–42.

Ulph, A. (1999) Environment and trade, in: H. Folmer and L. Gabel (eds.), *Principles of Environmental Economics II,* Cheltenham: Edward Elgar, pp. 479–528.

**Table 1.** Effects of changes in parameters on optimal tax rates[a]

| Parameter | Value | $r^h$ | $\tau_1^h$ | $\tau_2^h$ | $x_2^h$ | $x_2^f$ |
|---|---|---|---|---|---|---|
| $\alpha$ | 0.75 | 0.188 | 0.104 | 0.106 | 3.612 | 2.332 |
| | 0.55 | 0.161 | 0.155 | 0.159 | 3.728 | 2.399 |
| | 0.35 | 0.137 | 0.215 | 0.219 | 4.057 | 2.590 |
| $\beta$ | 0.65 | 0.173 | 0.117 | 0.120 | 3.480 | 2.381 |
| | 0.45 | 0.147 | 0.146 | 0.149 | 3.357 | 2.572 |
| | 0.25 | 0.126 | 0.178 | 0.181 | 3.422 | 2.941 |
| $\bar{k}^h$ | 8 | 0.214 | 0.094 | 0.096 | 3.099 | 2.304 |
| | 6 | 0.251 | 0.083 | 0.085 | 2.543 | 2.267 |
| $\bar{k}^f$ | 4 | 0.190 | 0.105 | 0.107 | 3.561 | 1.995 |
| | 2 | 0.194 | 0.107 | 0.108 | 3.408 | 1.223 |
| $\bar{y}^h$ | 10 | 0.202 | 0.067 | 0.068 | 4.060 | 2.352 |
| | 8 | 0.196 | 0.081 | 0.083 | 3.858 | 2.344 |
| | 4 | 0.178 | 0.147 | 0.150 | 3.292 | 2.315 |
| | 2 | 0.161 | 0.265 | 0.271 | 2.809 | 2.286 |
| $\bar{y}^f$ | 10 | 0.206 | 0.057 | 0.058 | 4.279 | 2.658 |
| | 8 | 0.206 | 0.057 | 0.058 | 4.259 | 2.253 |
| | 4 | 0.189 | 0.104 | 0.106 | 3.581 | 2.122 |
| | 2 | 0.191 | 0.105 | 0.107 | 3.528 | 1.805 |
| $\varepsilon$ | –4 | 0.349 | 0.194 | 0.194 | 4.032 | 2.486 |
| | –6 | 0.431 | 0.239 | 0.220 | 4.160 | 2.531 |

[a] The initial parameter values are set to $\alpha = 0.75$, $\beta = 0.75$, $\bar{k}^h = 10$, $\bar{k}^f = 5$, $\bar{y}^h = \bar{y}^f = 6$, and $\varepsilon = -2$. In the experiments the parameters given in the first column are varied using the values provided in the second column.